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FEDERAL EXPERIMENT STATION IN PUERTO RICO

of the

UNITED STATES DEPARTMENT OF AGRICULTURE

MAYAGUEZ, PUERTO RICO

BULLETIN No. 45

LIFE HISTORY, HABITS, AND CONTROL OF THE COCONUT RHINOCEROS BEETLE IN PUERTO RICO

by

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Entomologist

Issued November 1948

UNITED STATES DEPARTMENT OF AGRICULTURE

AGRICULTURAL RESEARCH ADMINISTRATION

OFFICE OF EXPERIMENT STATIONS

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WASHINGTON, D. C. — NOVEMBER 1948

LIFE HISTORY, HABITS, AND CONTROL OF THE COCONUT RHINOCEROS BEETLE IN PUERTO RICO

By Harold K. Plank, *Entomologist, Federal Experiment Station in Puerto Rico*

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INTRODUCTION

The coconut rhinoceros beetle (*Strategus quadrifoveatus* (Palisot de Beauvois))[1] has been recognized as a serious pest of coconuts in Puerto Rico for many years. It was originally described as *Scarabaeus quadrifoveatus* by Palisot de Beauvois (*12, p. 74*)[2] in 1807 from specimens collected in "America." The common name is derived from the coconut-feeding habits of the insect and the fact that the middle and longest of three projections on the front of the prothorax of the male resembles the horn of a rhinoceros (see fig. 1). This beetle is much

[1] Order Coleoptera, family Scarabaeidae. Determined by E. A. Chapin, U. S. National Museum, Washington, D. C.

[2] Italic numbers in parentheses refer to literature cited, p. 34.

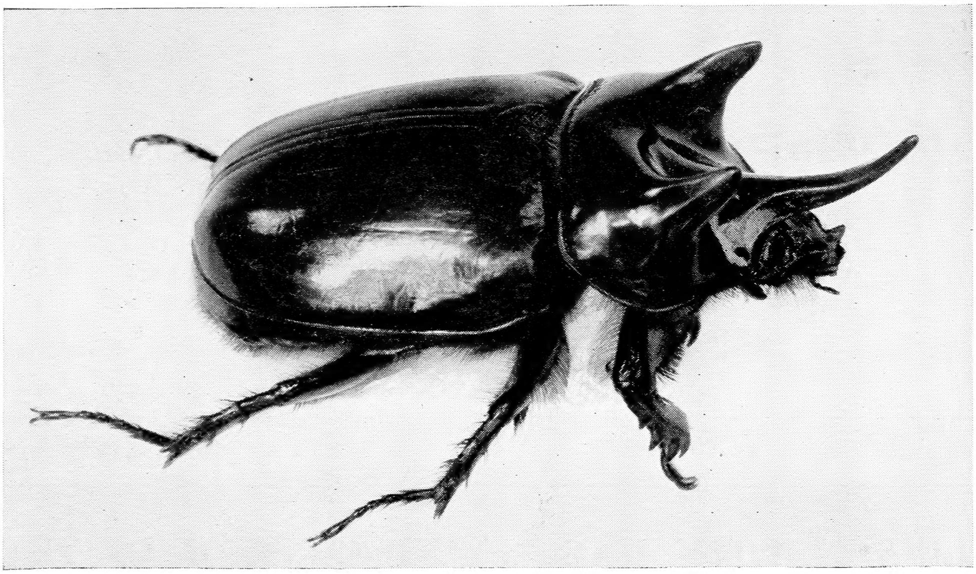

FIGURE 1.—Male coconut rhinoceros beetle (*Strategus quadrifoveatus*) showing characteristic horns on front of prothorax. This beetle was taken burrowing from below into the heart of a seedling coconut palm. On some specimens the middle horn is much shorter and the lateral ones are only moderate elevations in the natural curvature of the prothorax. (Compare with fig. 8, *B*.) × 1.4.

larger than the rhinoceros beetle of the Far East, *Oryctes rhinoceros* Lind., with which it may be confused but which does not occur in this part of the World. *Oryctes* has a somewhat shorter life cycle and its habits are much more destructive (*4, p. 103*). The principal injury caused by *Strategus* comes from the feeding of the adults on the germinal tissue and growing point of young coconut palms, into which they burrow from a point at or just below the surface of the ground. The adults of *Oryctes*, on the other hand, burrow more often from above than below into the heart and central spindle of mature as well as of young palms and seriously damage many more kinds of palms and other plants, including sugarcane (*4, p. 103*). The larvae of both species are not known to attack living plants. The larvae of *Strategus* feed on the decaying wood of trees, particularly coconut and other palms; those of *Oryctes* also live in this kind of material and, in addition, can complete their development in accumulations of other decomposing vegetable matter, such as garbage, coffee and cacao hulls, and stable manure, and coconut husks when mixed with other refuse (*4, p. 103*).

According to Leonard (*8, p. 52*), the first published reference to *Strategus* as an enemy of coconuts in Puerto Rico was made in 1896 by López Tuero (*9, pp. 205–206*). Since then, numerous articles have appeared which treat mostly of the extent of the damage caused and suggest various measures of control. The most detailed account of the life history has been given by Smyth in his second report on the white-grubs attacking sugarcane, published in 1920 (*19, pp. 21–29*).

After the hurricane of 1928, the rhinoceros beetle was reported by Leonard (*6, pp. 116–117*) to be more injurious than formerly. This storm and the hurricane of 1932 uprotted or broke off many established and bearing coconut palms over the whole island. The decay of this wood during subsequent years greatly increased the supply of food for

the larvae and ultimately resulted in an enormous increase in the population of the beetle. Growers, already handicapped by the loss of production, were unable to prevent the consequent widespread destruction of palms planted to replace those blown down. Federal rehabilitation agencies lent financial assistance in the reestablishment of groves, but much of this effort was nullified by beetle damage. So serious was the loss from this pest that in July 1934 the United States Department of Agriculture was asked to investigate the situation and to make recommendations for control. This paper reports the results of studies and observations made by the writer and reviews previous work carried on by others.[3]

DISTRIBUTION AND INJURY

The coconut rhinoceros beetle is well distributed over the island of Puerto Rico and particularly abundant along the humid coast lines where coconuts are grown extensively. Smyth (*17, p. 141; 19, p. 23*) states that besides Puerto Rico it has been recorded from the Dominican Republic and Haiti, and to this Wolcott (*23, p. 374*) adds the U. S. Virgin Islands.

Regions of greatest wind damage, not necessarily those of greatest production, have ordinarily been the parts of the island suffering the most injury from this insect. Usually in about 2 years after each major hurricane reports have appeared of extensive beetle damage to replanted and other young palms. The first record of the amount of damage beyond the characterizations "destructive" or "particularly injurious" was that published by Smyth in 1919 (*18, p. 124*). He estimated that, during the second year after the hurricane of 1916, 1 percent of the palms under 1 year of age in a large plantation near Manatí were killed by this insect. Two years later he stated (*19, p. 27*) that some plantation owners replanted yearly from 1 to 5 percent of their nursery palms because of rhinoceros beetle injury.

In the spring of 1935, the Puerto Rico Emergency Relief Administration estimated that out of a total of 788,000 palms established in Puerto Rico before 1928, some 200,000 (25.4 percent) were destroyed by the hurricanes of 1928 and 1932 (*10*, p. *19*). These storms caused the greatest amount of damage on the northeast coast and comparatively little less on the west coast. Both coasts have been regions of greatest coconut culture on the island, and with the decay of the trees felled by the storms, they became the regions of greatest abundance of the beetle. On the northeast coast, the owner of 1 typical grove of about 40,000 palms, in which 22,000 had been blown down, estimated that the beetle destroyed 60 percent of the young replanted palms.

[3] This work was initiated by the writer during the summer of 1935 while on the staff of the Bureau of Entomology and Plant Quarantine. It was at first carried on under Departmental funds for studies of insects in Puerto Rico and with faciilties provided by the Federal Experiment Station at Mayaguez. On October 1, 1936, the writer was transferred to the Office of Experiment Stations, and the work was concluded under the regular appropriations of the above station. Many helpful suggestions were received from D. L. Van Dine, formerly in charge of Fruit Insect Investigations, Bureau of Entomology and Plant Quarantine, under whose general direction the work was carried out. Cooperation in field collections and other studies was received from officials and field staff of the Coconut Project of the Puerto Rico Emergency Relief Administration and successive agencies, and from various grove owners in the vicinity of Mayaguez.

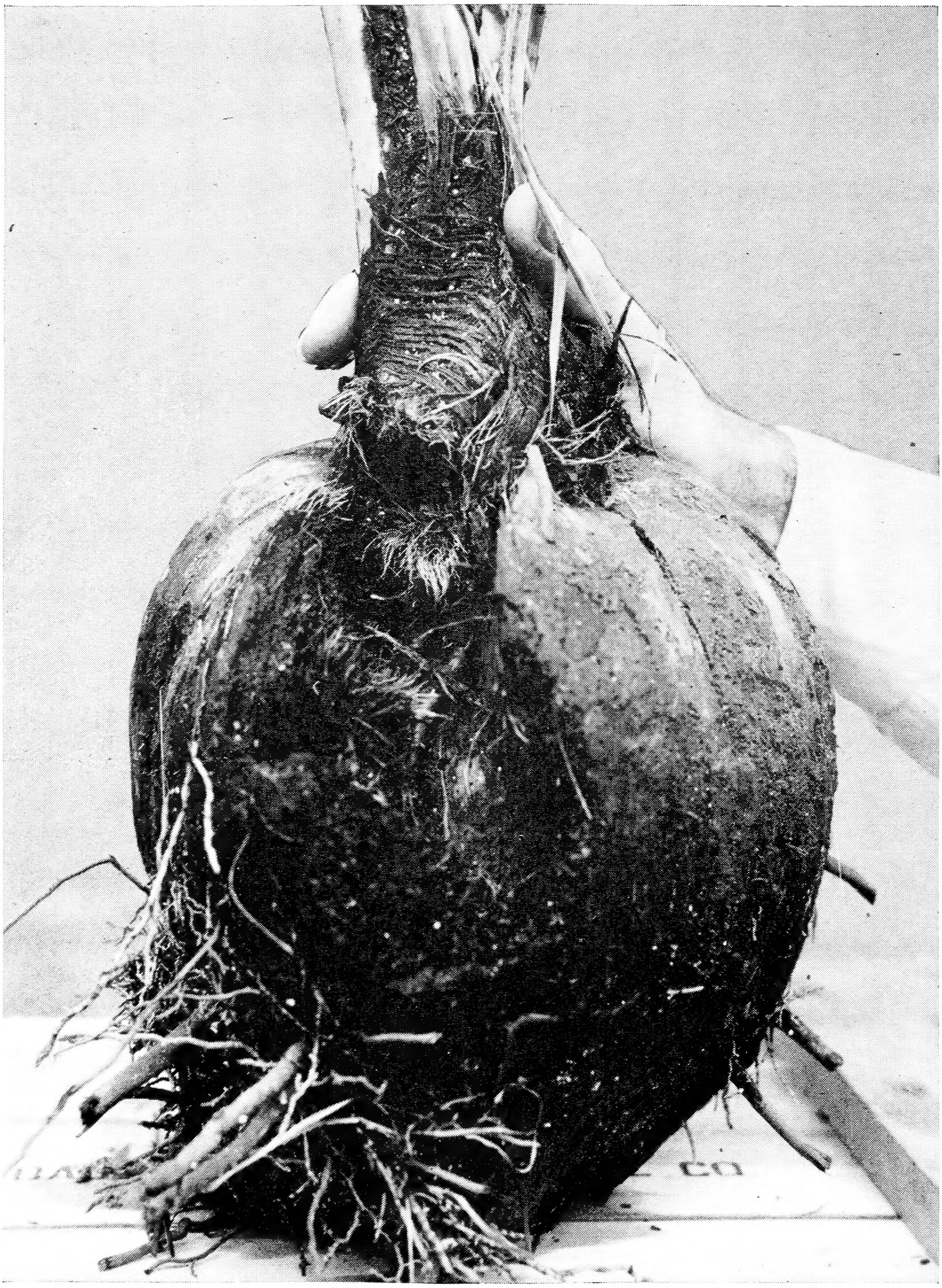

FIGURE 2.—Injury caused by adults of *Strategus quadrifoveatus* in base of seedling coconut palm. Note large jagged hole in husk and round hole through base of sprout. Although the outer leaves remained green for sometime, the central ones soon died and turned brown as a result of the killing of the growing point of the palm. This damage occurred in about 2 months after planting.

On the western end of the island the loss of replants was considerable but more localized. One grower near Mayaguez reported a loss of 55 percent during the 3 years following the hurricane of 1932. In other locations where there was also a large amount of decaying wood in or near the groves some growers estimated even higher percentages of

replants lost during the same period. Typical of many groves in this region was one examined by the writer in the fall of 1935. In an area of about 2 acres, previously occupied by 104 old palms, 12 palms had been blown down and were decaying and serving as breeding material for large numbers of rhinoceros beetle larvae. Of 53 palms (replants and volunteers) up to 3 years old growing in this area, 9, or 17 percent, were killed by the beetle and 11, or 21 percent, were attacked but still alive. A year later 16 palms, or 30 percent, were dead from this cause and 27, or 51 percent, were attacked but still alive.

Attack on the husk of the nut and the base of the sprout by the adult is often very savage, and death of the young palm, with typical symtoms of dead and dry center leaves, may occur within a month after planting (see fig. 2). Ability of the beetle to inflict fatal injury varies inversely with the age of the palm. Young bearing trees with trunks, i. e., from 8 to 10 years of age, have been reported as being killed by beetles entering at the base of the leaves about the soft part of the upper trunk and then burrowing upward into the heart and growing point of the palm. However, such cases were found to be rare, and it is believed from numerous observations that liability to fatal attack decreases rapidly after the young palm begins to form a trunk. Under favorable growing conditions in Puerto Rico, this would be at about 3 years after planting. The comparatively small amount of injury that occurs after this age has been observed usually to take the form of shallow holes made in the soft tissue of the upper part of the trunk, as shown in figure 3,*A*. As the palm grows older the leaves are shed and these holes become uncovered and with age gradually appear as

FIGURE 3.—Holes made by adults of *Strategus quadrifoveatus* in trunk of coconut palms: *A*, Shallow hole in axil of leaf, bent down in left foreground, and under fibrous strands of adjacent leaf base, all about 2.5 feet from the ground; *B*, holes in old, bearing palm up to about 6 feet from ground made when the palm was young. Large hole in middle is about 10 inches deep and has an upward direction. This type of injury, sometimes seen in heavily infested districts, may seriously weaken resistance to high winds.

those shown in figure 3, *B*. Sometimes, as mentioned by Smyth (*18, p. 124*), these holes are so enlarged that the palm is weakened and easily blown over or broken off by high winds.

According to the 1940 Census, the 10 highest producing municipalities in the island had 359,116 palms of bearing age, or 60 percent of the total reported, and an average production of 36 coconuts per palm (*15, pp. 136, 291*). In that year 76 percent of the total island production was exported at a value of about $20 per thousand nuts.[4] On this basis, the immediate loss in production of a bearing palm blown down by a hurricane would not appear to be great. However, at more recent prices of between $100 and $200 per thousand, the monetary loss would be considerable, and to this must be added eventually the cost of bringing the replanted palm into the same state of production as the original one. This may require from 7 to 10 years, and the cost will be doubled by the approximately 50–50 chance that the replacement, if not protected, will be killed by the rhinoceros beetle. The loss caused by the beetle includes not only the cost of the killed seedling and the labor of replanting, but also the material, time, and labor consumed on each successive replant until the final one comes into bearing.

LIFE HISTORY

The life history of the coconut rhinoceros beetle was studied by Smyth in 1916 (*16, pp. 46–47*) and 1920 (*19, pp. 21–28*). In the present work opportunity was afforded to verify some of these observations and to supplement the information given on the early stages of development.

Egg

The relatively large, nearly globular to oblong-oval eggs of this insect are often found scattered loosely in the softer parts of moist, decayed wood. Usually, however, they are concealed in small cells having walls composed of minute pieces of wood mixed with soil. The interior surface of these cells is smooth and the inside diameter is about 1 millimeter greater than the dimensions of the egg, which allows ample room for expansion of the egg during incubation. In handling freshly deposited eggs extreme care had to be taken not to puncture the delicate, pliable eggshell. Many eggs burst of their own accord when removed from their moist surroundings and exposed for only a few minutes to the outside atmosphere,

Seven eggs measured the same day they were deposited varied from 2.9 mm. to 3.1 mm., average 3.0 mm., in diameter and 3.7 and 4.0 mm., average 3.8 mm., in length. As incubation proceeds, the eggs expand until they may be nearly one-fourth greater in each dimension than when newly deposited. The largest egg of more than 100 reared or collected in decaying coconut palm wood measured 4.5 by 5.4 mm. 2 days before hatching.

Newly deposited eggs are opaque and ivory white and have a smooth surface without markings. The surface of some appears to be mat, while that of others has a slight luster. During incubation they become somewhat translucent and after about 10 days assume a pearly white

[4] Department of Agriculture and Commerce. Annual book of statistics of Puerto Rico, fiscal year 1942–43. 208 pp. San Juan. 1945. [Processed.] (See p. 202.)

color and change later to dull ivory. During the last week of incubation, the appearance of the egg is somewhat like that of a small inflated rubber balloon so stretched in places that the surface becomes slightly shiny. These shiny areas are without regular pattern and become larger as the egg approaches hatching. Under a hand lens the margins appear to be finely granular, the granules becoming closer together as they blend into the surrounding apparently unstretched surface. Beginning about 3 days before hatching the tip of the mandibles and the middle segments of the abdomen of the larva become distinguishable through the eggshell. The shape of the egg at this time is usually oval, but some hatching eggs were found that were nearly globular. The larva breaks through the shell by means of the chitinized tips of its mandibles. Eggs in various stages of incubation are shown in figure 4.

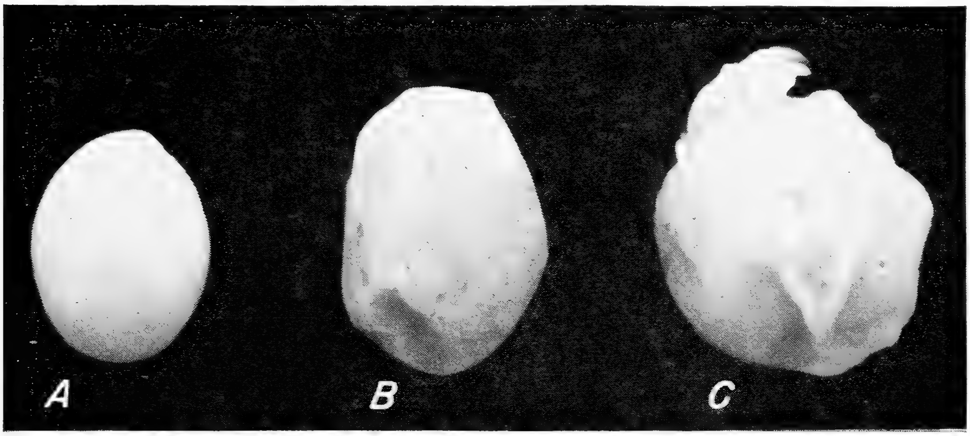

FIGURE 4.—Eggs of *Strategus quadrifoveatus* in various stages of incubation: *A*, Newly deposited; *B*, 2 days before hatching (fresh specimens are oval to globular); *C*, hatching—Note head, mouth parts, and legs of larva being freed through longitudinal break in eggshell. × 7.

The incubation period of 51 eggs of known date of deposition was determined in individual 1-ounce salve-box cages containing moist decayed wood of coconut and buried in the same kind of material in the laboratory. The data secured are summarized in table 1.

TABLE 1.—*Length of the incubation period of eggs of Strategus quadrifoveatus deposited from February to August 1936*

Period (days)	Eggs	Total time	Period (days)	Eggs	Total time
	Number	*Days*		*Number*	*Days*
13	1	13	24	1	24
15	16	240	25	1	25
16	11	176	34	1	34
17	16	272			
18	2	36	Total	51	858
19	2	38	Average		16. 8

It will be noted that under these conditions the length of the incubation period ranged from 13 to 34 days and averaged 16.8 days. The eggs having the shortest period were deposited in June and July,

while those with the longest were laid in February when weather conditions were somewhat cooler, as shown in table 2.

TABLE 2.—*Monthly rainfall and mean temperatures at Mayaguez, P. R., 1935 and 1936*

Month	1935				1936			
	Rainfall	Temperature			Rainfall	Temperature		
		Mean maximum	Mean minimum	Average		Mean maximum	Mean minimum	Average
	Inches	° *F.*	° *F.*	° *F.*	*Inches*	° *F.*	° *F.*	° *F.*
January	1. 53	86	61	73	1. 48	86	63	74
February	7. 19	86	60	73	. 44	88	[1] 62	75
March	3. 40	87	[2] 61	74	. 12	[3] 89	62	75
April	2. 97	88	62	75	3. 53	[3] 90	66	78
May	8. 93	88	65	76	9. 48	88	68	78
June	7. 31	89	66	77	11. 64	[3] 90	69	80
July	9. 09	[3] 90	67	78	7. 84	90	68	79
August	7. 33	90	68	79	9. 39	89	69	79
September	14. 69	90	68	79	5. 48	[3] 89	68	78
October	8. 26	88	66	77	10. 73	88	68	78
November	6. 85	87	65	76	3. 09	86	65	75
December	3. 80	87	65	76	3. 67	85	63	74

[1] Minimum of 57° for 1936 occurred during this month.
[2] Minimum of 56° for 1935 occurred during this month.
[3] Maximum of 95° for both years occurred during these months.

Larva

The newly hatched larva is a somewhat slender, curled grub about 10 mm. long having a prominent, deep-amber to black head (see fig. 5,*A*). Shortly after emerging from the egg, the larvae have been observed to feed on their empty eggshells, which they consume in about 2 hours. Subsequent feeding is confined to the decayed wood in the medium in which the eggs were deposited.

For rearing, the young larvae were kept in their incubation cages for a week or two and supplied with moist decayed coconut wood. As they increased in size they were transferred to 4-ounce and thence to pint tin cans with friction lids and supplied weekly or oftener with the same kind of food. Small holes or slits were punched in the lids and bottoms of these cans for ventilation and drainage. To reduce unnatural variations in temperature and moisture content, these cans were buried outdoors in the shade beneath several inches of decayed coconut wood mixed with a small proportion of sandy soil and covered with a layer or two of palm leaves.

As the larvae eat their cast skins, including the head capsule and sometimes the mandibles, shortly after molting, the width of the head was used to determine the rate of development of reared larvae and the instar of those found in field collections. A vernier caliper was used for this purpose and all head widths were read to the nearest 1/10 millimeter.

First instar.—Based on the measurement of 296 larvae reared from the egg and collected in decayed wood, the average width of the head

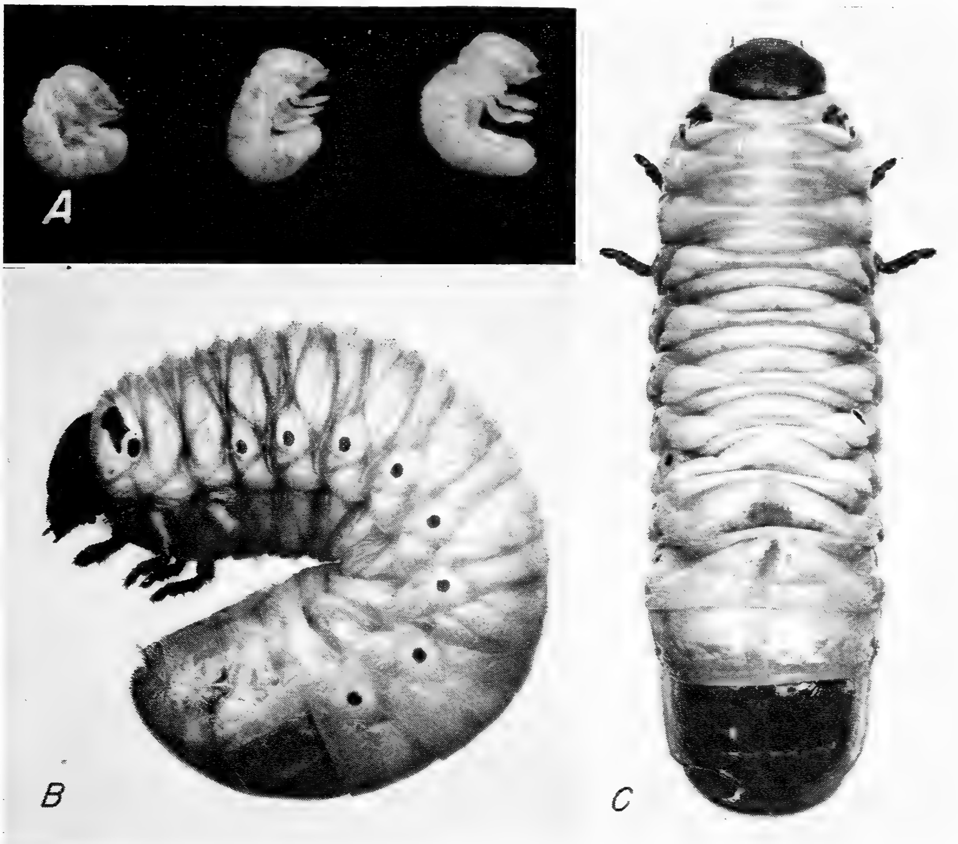

FIGURE 5.—Larvae of *Strategus quadrifoveatus* found in decayed coconut wood: *A*, Newly hatched, lateral view; *B*, full-grown, lateral view; *C*, full-grown, dorsal view. *A* × 2.4; *B* and *C* × 1.1.

of the first instar was 3.6 mm. One larva was found with a head width of 2.8 mm. as the smallest and 7 measured the maximum of 4.0 mm. Forty-eight of these larvae reared from September to the following July averaged 73 days in development from hatching to the first molt; 1 larva was observed to molt in 46 days, while 2 larvae needed 114 days. During the first instar the body increases in length from 10 mm. to 28 mm. (*19, p. 25*).

Second instar.—The head width of 176 larvae of this instar in both reared and field-collected material averaged 6.7 mm., 4 larvae having the minimum width of 5.5 mm. and 3 the maximum of 7.7. mm. One larva reared in the laboratory developed through 165 days, about 5.5 months, before molting the second time. Eight other larvae in outdoor cages examined at monthly intervals remained from 3 to 8 months, or an average of about 4.75 months, in the second instar. According to Smyth (*19, p. 25*), the body in this instar increases to 55 mm. in length.

Third instar.—The average head width of the third-instar larva, based on the measurement of 249 field-collected specimens, was 12.3 mm., the minimum being 9.6 mm. and the maximum 14.1 mm. No data on the exact duration of this instar were obtained because of difficulty in rearing. However, 6 field-collected larvae kept in outdoor cages examined monthly spent from 6 to 8 months, averaging about 7 months, in the third instar, while 12 others were still in this

instar when examinations were discontinued 9 months after the second molt. The time of these last in the third instar may have been prolonged somewhat by the rearing methods employed.

In this instar the body increases enormously in size and the much-distended abdomen becomes filled with masticated particles of decayed wood which the larva has ingested from the medium in which it developed. In extensive field collections many specimens were found that measured 89 mm. long by about 25 mm. in greatest diameter. One larva with a head width of 13.5 mm. had an over-all length of about 100 mm. 5 months before it began to change to the pupa state. Typical full-grown larvae are shown in figure 5,*B* and *C*.

The head of the full-grown larva is round or nearly so and black in color. As will be noted in figure 5,*B*, each side of the body bears nine dark-brown subcircular disks. These are the spiracles or breathing pores of the insect. The hairs and spines, with which the segments of the body are sparsely clothed, are brown in color and tend to point backward (see fig. 5,*C*). With the exception of the amber color of the head of newly hatched or freshly molted specimens, the foregoing characters apply also to the first and second larval instars.

FEEDING HABITS OF THE LARVA

Equipped with powerful mandibles, third-instar larvae, and even second-instar larvae, are capable of biting into very hard substances.

FIGURE 6.—Holes made in tin-can rearing cages by larvae of *Strategus quadrifoveatus*: *A*, Scratches in metal and enlargement of vent holes in lid made by full-grown larva; *B*, a second-instar larva made and escaped through this hole in bottom in 3 months. × 0.8.

While being held for rearing in tin cans, some larvae have gnawed their way through the bottoms. A typical example is shown in figure 6,*B*. In large cans held indoors this gnawing could sometimes be heard at a considerable distance. Although caged larvae always made an effort to escape, especially wherever a "tooth hold" with their mandibles could be secured, such efforts were successful only where the cans had begun to rust. Evidence of this kind was frequently observed in outdoor rearing cages as shown in figure 6,*A*. Overcrowding may have been responsible for this, as it usually occurred in cans where a number of larvae were confined and the volume of suitable food material was limited. Under crowded conditions the larvae were cannibalistic, which probably helps to account for the fact that few larvae are found in small pieces of decaying wood.

Normally feeding on decaying coconut wood, the larvae of the coconut rhinoceros beetle can develop to maturity on the wood of a number of other plants. Larvae have been found in various stages of development in the rotting wood of *Inga laurina* (Sw.) Willd. ("guamá"), *Inga inga* (L.) Britton (=*I. vera* Willd.) ("guaba"), *Citrus sinensis* (L.) Osbeck ("china"), *Spathodea campanulata* Beauv. ("tulipán africano"), *Spondias* sp. ("jobo"), and various palms other than coconut, particularly *Sabal causiarum* (Cook) Beccari ("palma de sombrero"). The net result of infestation in all of these is nearly complete pulverization of the interior of the piece infested.

Because they were readily available after hurricanes, pieces of the trunk of coconut and other palms have been often used as fence posts or in structures in contact with the ground. However, to prevent the formation of reservoirs for the development of rhinoceros beetle infestations, the Department of Agriculture of Puerto Rico promulgated Local Quarantine No. 1, which prohibits such uses.[5] The parts of the trunk in or touching the ground or remaining moist soon begin to decay and shortly thereafter become infested with larvae of the coconut rhinoceros beetle. Collection records have revealed a considerable capacity of this material to serve as a medium in which this pest can multiply to infest surrounding coconut palms.

Smyth stated that the larvae thrive on partly rotted coconut fiber (*19, p. 25*). From this it might be inferred that the adults are attracted for oviposition purposes to decaying coconut husks, either those about the nut of newly planted seedling palms or in discarded piles as often seen in many coconut groves, and that the resulting larvae would develop in this kind of material.

Evidence was obtained that under certain conditions the larvae of the coconut rhinoceros beetle will feed on the rind of decaying coconut husks, but not on the fiber. Such feeding was observed on the husk of a seedling palm planted in an outdoor cage. The beetles confined in this cage had nowhere else to oviposit than in the sand in which the palm was planted. When the palm was dug up 3 months after beetles had been admitted, it was found that some eggs were deposited near the nut and that some of these eggs had hatched. The resulting larvae,

[5] Menéndez Ramos, R. Cuarantina interna sobre el escarabajo rinoceronte (*Strategus quadrifoveatus* P. B.) de la palma de coco. Puerto Rico Dept. Agr. and Com., Servicio de Sanidad Vegetal, Cuarantina Interna Núm. 1, 1 p. Promulgada en San Juan, P. R., 10 mayo 1935. 1935. [Processed.]

having no other food, had fed on the outer covering or rind of the disintegrating husk, but the fibers themselves were not attacked (see fig. 7). Although numerous seedling palms attacked by the adults have been examined under field conditions, no larvae have been found near or in the husks and no larval feeding on the rind or the husk has been observed.

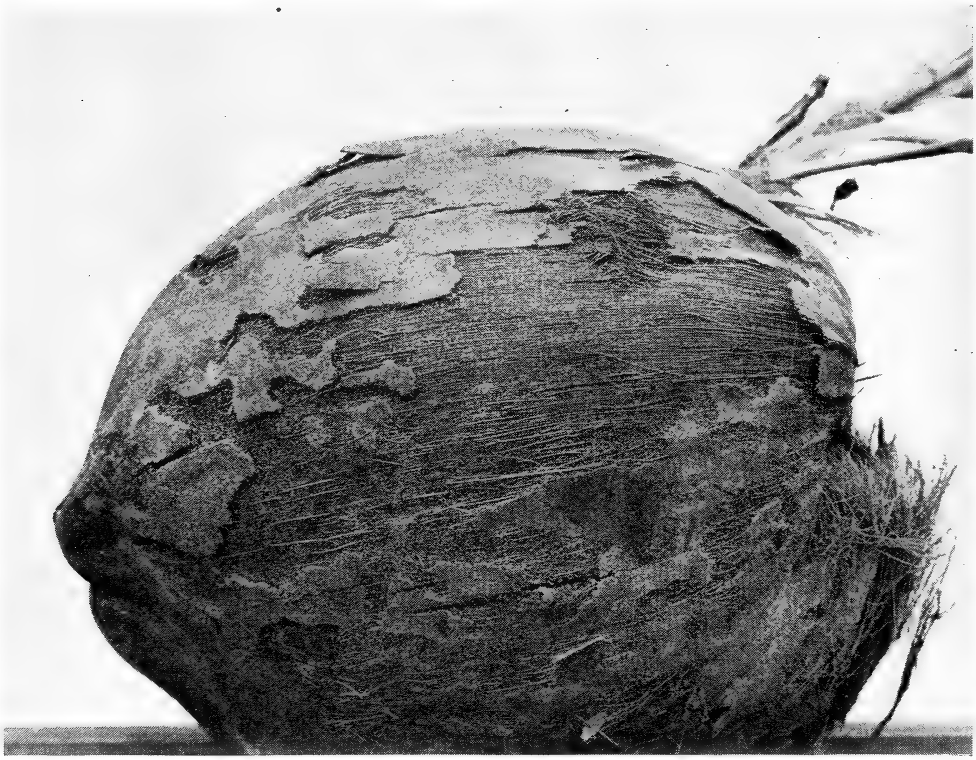

FIGURE 7.—Feeding on rind of seedling coconut by young larvae of *Strategus quadrifoveatus* in confinement. Feeding of this character has been noted only where the beetles were kept with the nut in a cage and could not oviposit elsewhere. Larval feeding on the disintegrating husk of either planted or unplanted coconuts has never been seen under open field conditions.

Unlike the larvae of *Oryctes rhinoceros* of the Orient (*4, p. 102*) and *Strategus anachoreta* Burm. of Cuba and possibly Trinidad, the larva of *S. quadrifoveatus* does not live in decaying coconut husks and vegetable refuse other than the decaying wood of coconut and other trees. In the examination of numerous piles of coconut husks for evidences of rhinoceros beetle breeding, no piles accumulated for 2 years or less and only two that were older were found infested by scarabaeid larvae. In one pile about 3 years old, several May beetles (a species of *Phyllophaga*, probably *vandinei* Smyth) were taken, and three larvae, no doubt of this same species also, were found feeding on the fibers of decaying husks next to the ground.

In a 4-year-old pile the dismembered remains of a female coconut rhinoceros beetle were found and next to the ground a small first-instar larvae of the same species. In comparison, decaying coconut and other wood nearby was found heavily infested with numerous rhinoceros beetle larva in various stages of development. Efforts to

rear coconut rhinoceros beetle larvae on decaying coconut fiber were unsuccessful. It is evident that coconut husks cannot be considered to constitute more than an accidental breeding medium for this insect.

Prepupa

When the larva has become full grown it forms a cell nearly its own size in the mass of pulverized rotten wood in which it has lived. This cell is oblong to somewhat rounded and has fairly smooth walls on the inside. In it the larva passes a quiescent period, called the prepupal stage, preparatory to shedding the last larval skin. During this stage the body loses most of its curvature, becomes somewhat shorter, and takes on a dirty yellowish-brown color. The prepupal stage of 18 specimens observed over the period of July to the following January varied from 12 to 20 days and averaged 18 days.

Pupa

When the last larval skin is shed, the prepupa becomes a pupa. This stage is spent in the same cell originally made by the larva. When first formed the pupa is pale amber in color and very fragile. With the gradual hardening of the integument or outer covering of the body, the color changes to deep reddish brown but the body walls always remain more or less delicate. As will be noted in figure 8,*A*, the pupa resembles greatly the form of the adult, and in this condition it is often possible to determine the sex from the size of the protuberances on the thorax. The pupal stage of 60 individuals reared from July to September of the following year extended from 20 to 46 days and averaged 33 days.

Adult

After the pupal skin is shed, the resulting adult, like the newly formed pupa, is pale amber in color and rather fragile. During a variable period before it breaks through the walls of the pupation cell in which it emerged, the adult gradually assumes a characteristic dark reddish- or mahogany-brown color and hard texture. Seventy-one adults were observed to remain in their pupation cells from 2 to 10 days, the average time being 4 days.

Some adults of the coconut rhinoceros bettle are among the largest insects known, and much larger than any other species of insect in Puerto Rico. The male shown in figure 1, the largest encountered in this work, was 60 mm. long including the horn which was approximately 17 mm. long. The largest female (shown in fig. 8,*C*) measured 50 mm. long. These measurements approach those of the Solomon Islands elephant beetle (*Xylotrupes nimrod* Voet. (=*X. gideon* L.)), the largest of those mentioned by Smyth (*19, pp. 4–6*).

As will be seen in figure 1, the anterior horn of the male coconut rhinoceros beetle comes to a single point. In this respect it differs from the male of the much smaller sugarcane rhinoceros beetle of Puerto Rico (*Strategus barbigerus* Chapin), the horn of which is slightly divided at the tip (*19, p. 22*). The middle and the other two horns vary from short protuberances on the prothorax, as shown in figure 8,*B*, to the prolongations shown in figure 1. In fresh specimens the horns and the surface between them are sometimes highly polished like the rest of the body, but in adults that have burrowed for a time in

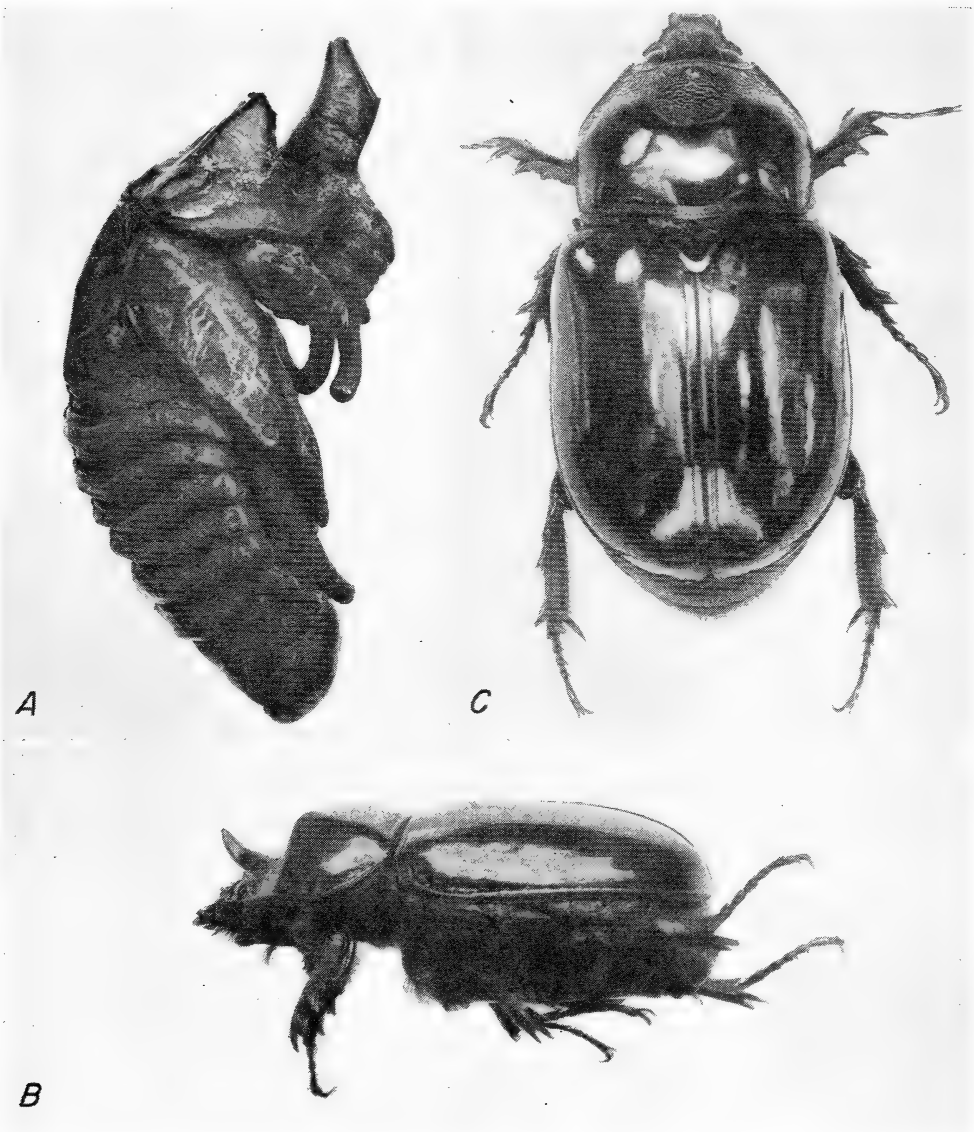

FIGURE 8.—Pupa and adult stages of *Strategus quadrifoveatus: A*, Pupa of a male; on uninjured specimens the horn is somewhat longer than that shown here. *B*, Adult male having medium to short horns on prothorax; note sculpturing of surface about base of front horn, characteristic upward curve of mandibles projecting from the head, claws on front legs, and sharp spines on middle and hind legs. *C*, Adult female; note characteristic absence of horns and sculpturing of front and margins of prothorax. × 1.4.

the sandy soil usually found about the base of coconut palms, these areas become tarnished or scratched. The front part of the prothorax of the female and sometimes that of the male is more or less etched with medium-fine lines as shown in figure 8,*B* and *C*. The tip of the abdomen of the male is rounded while that of the female tends to be pointed.

In contrast with those of the larva, the mandibles of the adult are flattened and somewhat fan-shaped in front. The teeth are terminal and slightly upturned, admirably suited to their use of cutting in a horizontal plane and lifting vertically (see figs. 1 and 8,*B*). As will

be noted in figures 1 and 8,*B* and *C*, the front tibiae bear stout claws fitted for digging, and the middle and hind tibiae bear sharp terminal spines fitted for pushing or bracing support.

HABITS OF THE ADULT

As might be judged from the shape of the mandibles and the absence of solid particles from the alimentary tract, the adult consumes little if any of the woody material in which it lives. That the principal, if not the only, food of the adult is the juices of the living plants it attacks is plainly indicated by its feeding habits.

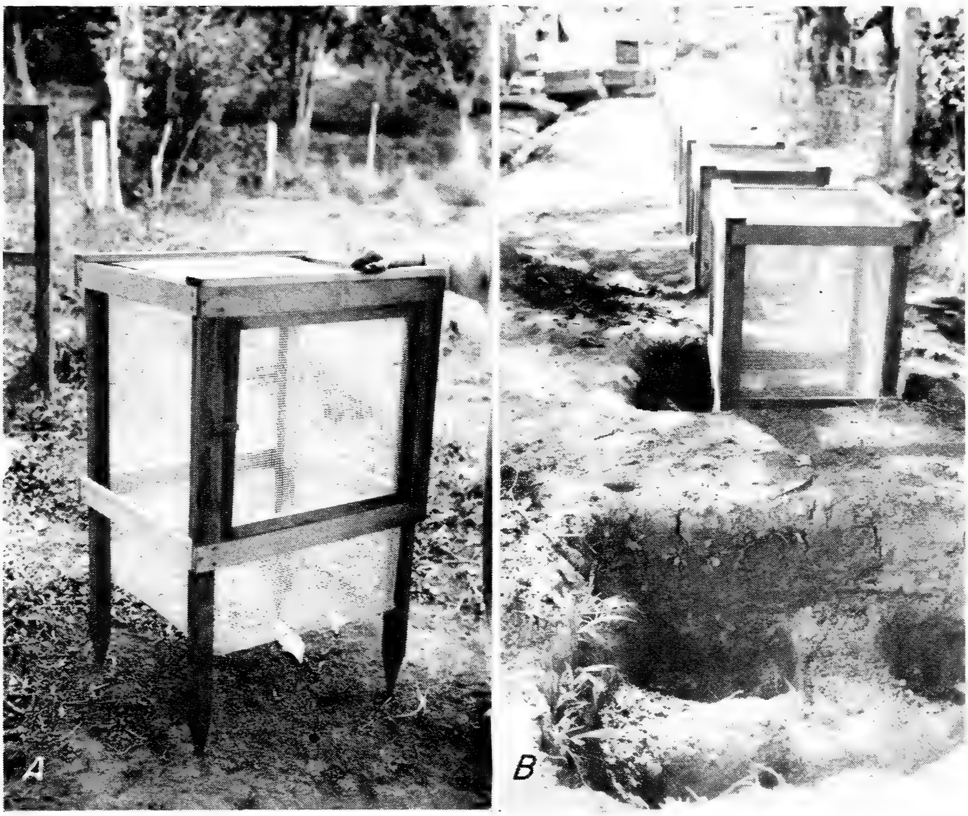

FIGURE 9.—Soil cage for observation of adults of *Strategus quadrifoveatus* under simulated field conditions: *A*, Lower 1 foot (that below door) is buried in ground and filled with sand for receiving a seedling coconut. *B*, In foreground, hole made to receive the legs and lower part of cage shown in *A*; in middle ground, such a cage is placed ready for filling lower 1 foot with sand and the outside with sand and soil; in background are completed cages planted with seedling coconut palms and stocked with beetles.

Observations on feeding habits in the field were supplemented by studies of adult behavior under simulated natural conditions in especially designed cages held outdoors. These cages, 3 feet high by 2 feet square with a door on one side, were made throughout of ½-inch square mesh galvanized iron wire cloth, standard grade, and fastened in a wooden frame as shown in figure 9,*A*. After the lower 1 foot of the cage was buried in the ground, as shown in figure 9,*B*, this part was filled with beach sand and a seedling coconut palm was planted in

the center. The cage was kept stocked with one female and one or several male beetles.

Almost immediately on being liberated the beetles began to dig into the sand, making characteristic holes about 1 inch in diameter like those commonly found in the soil about infested young palms in the field. (See figure 10.) When these holes were closed every day by smoothing out the sand, they would be found reopened the next morning. Evidently while feeding the beetles make frequent trips to the surface of the soil and probably also move about a great deal from one palm to another.

FIGURE 10.—Characteristic holes made in husk and soil about base of seedling coconut palm by adults of *Strategus quadrifoveatus*. These holes are about 1 inch in diameter and may contain from one to several beetles. The casting out of husk fibers about holes is typical of advanced beetle attack on young palms.

Entrance into the trunk of the young palm was usually made from a point about 2 or 3 inches below the surface of the ground where the soil was firm enough to provide adequate foothold. Adults were observed on numerous occasions to brace themselves with their middle legs, and sometimes with their hind ones also, while tearing apart with their powerful front legs the exceedingly tough outer covering of the sprout or husk. During the process the sharp mandibles were held firmly against the surface and moved sidewise. The tissues thus weakened or cut were moved aside by the front legs or shoved upward by an up-and-down movement of the head and prothorax. Male beetles having medium to long horns were able to make more rapid progress than the females. Fibers of the husk or trunk were cast out as shown in figure 10. Under cage conditions, the outer covering was usually penetrated during the first month after the beetles were

admitted. The succulent interior of the sprout was often reached within another week and, depending on the size of the sprout and the extent of the burrow, death of the palm was evident approximately 3 months later.

Sometimes during the first week after entrance had been made the beetles were seen to leave and return to their original burrow at the base of the sprout. This burrow was always extended to the point where the sprout came out of the nut. Beetles found in such situations had their mouth parts thrust firmly into the fresh tissues in the extreme interior where plant juices were liberated in greatest abundance.

When extremely numerous, the adults may sometimes burrow into and feed on the juices of older coconut palms, other palms, or even other plants, but instances of this kind are rare. Such attacks in the base, trunk, and top of bearing coconut palms have already been referred to. Attack on the "fish-tail" palm has been recorded by Wolcott (*24, p. 255*), and adult feeding similar to that on young coconut palms was found by the writer in young Borinquen royal palms (*Roystonea borinquena* Cook) and some palms of the genera *Phoenix* and *Pritchardia.* Adults have occasionally been found hollowing out the inside of growing sugarcane stalks (*19, pp. 21–23*).

In addition to the foregoing, adults may be found at one time or another in decaying wood of various kinds, especially that of coconuts, in which larvae will feed and develop (see Feeding Habits of the Larva, p. 10). However, their presence in this kind of material is not for the purpose of feeding but for emergence or oviposition.

The kind of plant material, that is living or dead, burrowed into depends a great deal on the age of the adult. When caged with different parts of the coconut palm, reared beetles from 2 weeks to several months of age preferred to burrow into husk fiber and fresh coconut meat; beetles of variable age collected at lights burrowed into husks and decaying wood, whereas some of the beetles collected in decaying wood were attracted to this material and some fed on coconut meat. These last were probably newly emerged, but those that continued to be attracted to decaying wood were in search of a suitable place in which to lay their eggs. Assuming that preference for husk fiber and coconut meat indicates attraction to seedling coconut palms for food, it would appear from the foregoing that the beetles start feeding on young coconut palms soon after emergence and continue to be a menace for several months thereafter. Two distinct movements of the adults are evident: One, from decaying wood to young palms for food and mating; the other, from young palms back to decaying wood for oviposition.

Although nocturnal in habit, the adults are only slightly attracted to lights. Efforts to catch them in light traps have been so unsuccessful as to suggest that those seen at lights arrive there by accident. Observations on the number attracted to lights were made in a coconut grove near Mayaguez where considerable emergence was taking place. From the beginning of September to the end of the following July only 22 adults were seen at two 15-watt lights in this grove. Four of these were males and 18 were females. Some of the females were gravid and in the laboratory deposited viable eggs.

REPRODUCTION

On account of rearing difficulties, it was possible to secure data on reproduction from only a few individuals.

Mating.—Copulation was observed on only one occasion. A male that emerged January 10 was confined a month later with a female that emerged January 7 in a 1-quart-can cage nearly filled with decaying coconut palm wood and supplied continuously with fresh coconut meat for food. Copulation was observed April 25, 109 days after emergence. The first eggs from this pair were deposited 9 days later, and egg-laying continued over 9 more days on 5 of which a total of 10 eggs were deposited. When the female died at the end of another 4 days, it still contained 4 well-developed eggs and numerous undeveloped ones. That mating at least sometimes takes place before flight to light has already been indicated.

Oviposition.—The female mentioned above was also observed in the act of oviposition. In the routine examination of the contents of the oviposition cage for eggs it was noticed that this female was unusually quiet and what appeared to be a yellowish-green fluid was extruding from the tip of the abdomen. After about 5 minutes this fluid was withdrawn, whereupon an egg was forcibly ejected. Under natural conditions it is possible that the female uses this fluid to construct the egg cell previously described.

For three females that emerged in January and February and were caged individually with males, the time from emergence to first oviposition varied from 68 to 118 days and averaged 99 days; number of days of oviposition 3 to 17, average 10; total eggs deposited 5 to 12, average 9; maximum daily oviposition 4; and life after last oviposition 2 to 6 days, average 4 days.

From three females collected at lights in January and June and handled in like manner, the following data were secured: Days of oviposition 6 to 31, average 15; total eggs deposited 5 to 32, average 14; maximum daily oviposition 7; life after last oviposition 7 to 20 days, average 12 days. After death many of both reared and field-collected females still contained eggs in various stages of development. From one 75 undeveloped eggs were dissected, from another 20 normal eggs and numerous undeveloped ones, and from various others from 1 to 11 eggs each. Under normal conditions the egg-laying capacity of the coconut rhinoceros beetle is undoubtedly much greater than that indicated by the foregoing laboratory records.

DURATION OF ADULT LIFE

By rearing field-collected pupae and last-stage larvae in outdoor cages and maintaining the emerging adults under the same conditions, it was possible to determine the length of life of 63 beetles emerging over the period from December to August of the next year. Under these conditions, these beetles lived for an average of 90 days each. Total life among 29 males varied from 61 to 193 days, averaging 96 days; that among the 34 females extended from 53 to 131 days, and averaged 85 days. Under natural conditions in the field some adults probably live for much longer periods. One male collected in a decaying coconut log on October 14 lived in outdoor and laboratory cages until the following May, or over a period of 218 days.

SUMMARY OF LIFE CYCLE

From the foregoing studies the length of the various stages in the life cycle can be summarized as in table 3.

TABLE 3.—*Summary of the duration of stages in the life cycle of Strategus quadrifoveatus, Mayaguez, P. R., July 1935 to September 1936*

Stage	Individuals observed	Duration		
		Minimum	Maximum	Average
	Number	*Days*	*Days*	*Days*
Egg	51	13	34	17
Larva:				
First instar	48	46	144	73
Second instar [1]	9	90	240	145
Third instar [1]	6	180	240	210
Prepupa	18	12	20	18
Pupa	60	20	47	33
Egg to emergence of adult				496
Adult:				
In pupation cell	71	2	10	4
Life before oviposition [2]	3	68	118	99
Oviposition [3]	3	3	17	10
Life after oviposition	6	2	20	8
Total life, male [2]	29	61	[4] 193	96
Total life, female [2]	34	53	131	85
Total life, undifferentiated	63	53	193	90
Egg to first oviposition				595

[1] Figures for this stage are approximate. (See text.)
[2] Including time in pupation cell.
[3] Normal oviposition period is undoubtedly larger. (See text.)
[4] One field-collected male, not included in this list, was kept alive for 218 days.

On account of the difficulty in handling already mentioned, only a few individuals could be reared from egg to second instar and none through the whole life cycle from egg to adult. However, by rearing various collections of field-collected material it was possible to secure an indication of the probable length of the later stages. Based on such observations of from 6 to 60 individuals, as recorded in table 3, the time from deposition of the egg to emergence of the adult would occupy 496 days and the complete life cycle from egg to egg a possible 595 days, or somewhat more than a year and a half.

SEASONAL DEVELOPMENT

Although the development of the coconut rhinoceros beetle appeared to be fairly uniform throughout the year, there were periods when one or more stages seemed to predominate over others. The extent to which this was true was shown by representative collections made at approximately monthly intervals of the stages present in decaying palm wood in coconut groves in the vicinity of Mayaguez. Each collection was held for rearing and examined for changes in development at the time of each succeeding collection. Unnatural mortality of

newly hatching larvae and reduced oviposition resulting from these conditions precluded the drawing of a reliable curve showing the incidence of each stage, but from the information secured it was possible to determine the approximate range of occurrence of each stage and the probable time of greatest abundance.

All stages except the egg were found in every month of the year. No eggs were encountered in October and November, but judging from the occurrence of first-instar larvae some eggs were probably present in the field during these months also and no doubt would have been encountered in more extensive field collections.

Eggs occurred in greatest abundance in June and July, although an appreciable number was obtained in the laboratory and in the field in February and September.

Larvae of early instars predominated throughout the summer months and those in the last instar mostly during the winter.

Pupae began to increase in transformation in December with a possible peak in May.

Adults, while seen at lights mostly in January and June, were at their peak of emergence in laboratory material and also most active in the field during June and July. As will be seen in table 2, the mean temperature at Mayaguez at this time of the year was at a sustained high.

NATURAL ENEMIES

The coconut rhinoceros beetle has few natural enemies. Although hundreds of individuals collected at various times during the year were kept under observation throughout their lives, no internal insect parasites were encountered on any stage, and none have been reported in the literature. A nematode identified as probably a new species closely related to *Rhabditis maupasi* Caul. et Seur.[6] attacked a number of field-collected eggs that were being reared in the laboratory. None was found actually attacking eggs in the field.

Diseases were sometimes seen on the larva. One, the green muscardine fungus (*Metarrhizium anisopliae* (Metsch.)),[7] was found on a few larvae from the north coast collected by Antonio Mellado, Jr., in charge of the coconut project, Puerto Rico Reconstruction Administration, Río Piedras. This fungus was previously reported by Smyth (*19, p. 28*) to attack all stages of the sugarcane rhinoceros beetle, particularly the pupa. Larvae confined for rearing have sometimes been attacked by a disease similar to that mentioned by Smyth (*19, p. 19*) as being caused by the bacterium *Micrococcus nigrofasciens*. This disease produced small black or dark-brown, hardened areas over various parts of the body. It was never found on specimens in the field.

Predators of various kinds were frequently encountered but none seemed to be able to affect any noticeable decrease in the population of this pest. Mites of the families Parasitidae and Tyroglyphidae have been the commonest of these,[8] and they were found, sometimes in considerable numbers, on dead and living specimens of all stages. They

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[6] Determined by G. Stiner, Bureau of Plant Industry, Soils, and Agricultural Engineering.

[7] Determined by Vera K. Charles, Bureau of Plant Industry, Soils, and Agricultural Engineering.

[8] Determined by H. E. Ewing, Bureau of Entomology and Plant Quarantine.

were of various colors, hyaline or white, pinkish gray, pinkish amber, and light amber. Mites of the former family, being truly parasitic, may have caused the death of some individuals; the tyroglyphids, which commonly infest stored vegetable products and the roots of living plants, no doubt occurred by accident. This was probably the case with *Rhizoglyphus phylloxerae* Riley,[8] the only mite found by the writer that could be definitely determined. This was found on a field-collected larva that died while being reared in the laboratory. Ordinarily, however, rearing of mite-infested rhinoceros beetle stages was accomplished without any apparent inconvenience from the mites. It is, therefore, doubtful that any effective degree of control occurs under natural conditions in the field. One species of the family Parasitidae [8] that was found on an adult taken in decaying coconut wood appeared to be symbiotic.

Ants of two species, *Monomorium crabonarium* sub-sp. *ebeninum* Forel and *Tetramorium simillimum* (F. Smith),[9] have been found feeding on dead beetles in outdoor soil cages and very likely have similar habits in the field. Although these ants were said by Dr. Smith to be highly predaceous, in these cases they probably began their attack after the beetles had died.

Larvae of the luminous elaterid, *Pyrophorus luminosus* Ill., commonly feed on scarabaeid or other larvae, particularly the white grubs of sugarcane (*24, p. 211*). However, this predator has never been recorded as feeding on the larvae of the coconut rhinoceros beetle. To see whether this were possible under the most favorable conditions, *Pyrophorus* larvae, collected in a pile of discarded coconut husks and in tunnels made by the banana root borer (*Cosmopolites sordidus* (Germ.)) in a banana corm were confined in the usual rearing cages and supplied with larvae of both insects. The *Pyrophorus* larvae quickly attacked and fed on the larvae of the banana root borer and consumed with nearly equal avidity the much-larger, second-instar larvae of the coconut rhinoceros beetle. The fact that rhinoceros beetle larvae do not make well-defined tunnels through which they may be easily reached is probably one reason why this predator has not been found associated with this pest in the field.

A test similar to the foregoing was made with adults of *Plaesius javanus* Erichson, a histerid predator that had just been received from Fiji by the Bureau of Entomology and Plant Quarantine to combat the banana root borer (*1, pp. 101–102*). In the open, two beetles were unable to attack a 2-inch third-instar larva of the coconut rhinoceros beetle because of its quick wriggling movements whenever approached. However, in loose decayed coconut palm wood where there was less freedom, these beetles consumed one larva weekly for several weeks leaving nothing but the head capsule and the larval skin. One of the beetles was thus kept alive for 5 months and the other for 6 months. Whether this predator, if it becomes established, will also attack larvae of the coconut rhinoceros beetle in the field remains to be determined.

Additional natural enemies of this and the sugarcane rhinoceros beetle have been recorded by Smyth (*17, p. 141*) to be herons, owls, mongooses, hogs, poulty, and rats. He stated (*19, p. 19*) that of these the mongoose was probably the most important, since scarabaeids had

[9] Determined by M. R. Smith, Bureau of Entomology and Plant Quarantine.

been found to constitute a portion of its food. Smyth also reported (*19, p. 28*) the finding of the mite *Tyroglyphus hetromorphus* Felt on grubs collected by G. N. Wolcott in decaying palm wood in the Dominican Republic.

Box (*2, pp. 303, 339–341*), working with the large scoliid wasp, *Campsomeris* (*Dielis*) *atrata* F., which presumably parasitizes *Strategus* larvae in Puerto Rico, readily secured oviposition on larvae of *S. barbigerus* but, because of diseased stock, failed to rear it through to the adult stage. However, he found the adult to be quite common in certain localities in Santo Domingo where *Strategus* larvae were also present, and suggested that this parasite be imported for rearing and liberation on this species and *S. quadrifoveatus*. Since *C. atrata* has been present in Puerto Rico for many years (*24, p. 563*) and during this time has not been found to parasitize rhinoceros beetle larvae of its own accord in the field, it is questionable whether additional colonization will favorably change more than temporarily its present status as an enemy of this pest.

CONTROL

A number of measures for the control of the coconut rhinoceros beetle have been recommended by various writers, but little has been recorded as to the results secured. Many of these measures were investigated in the present work, and some of the most important were tested on a field basis.

Hand Collection

Collection of the adults by means of nets was recommended by Smyth (*17, p. 141; 19, p. 29*), who suggested that this might easily be done in the evening while the beetles are flying about the grove. No data are available as to the number of beetles that can thus be eliminated over a given period.

Destruction of the beetles while they are attacking young palms was recommended by Wolcott (*23, p. 376*) and has given immediate results. This practice has been especially effective during the months of June and July, when adult emergence and activity are at their height. Logically, this is the best time to combat this stage of the rhinoceros beetle, since it takes advantage of the first movement of the adult from emergence to feeding. Destruction of the adults at this time controls them before they have had a chance to do much damage and before they have started to reproduce.

As previously pointed out, it is at least several days after the beetles begin their attack until they reach the growing point of most young palms. In the meantime their entrances, as shown in figure 10, are easily detected. Beginning immediately after planting, semiweekly, or even weekly, examinations of the soil surrounding newly planted palms will reveal the presence of any beetles before fatal damage has been done. The beetles found inside can be killed with a stick or other pointed implement or extracted and killed by means of a piece of stiff wire with barbs or a sharp hook on the end. All holes made in the soil are then closed and the surface smoothed out for a radius of about a foot around the palm, so that any attempt at entrance by other beetles may be found and similarly dealt with at the next inspection.

González Ríos (*5, pp. 15, 16*) suggested plugging the holes made by the beetles with a piece of cotton moistened with carbon disulfide.

To kill the beetles in the few holes sometimes found in the upper trunk of bearing palms, some growers are said to have made it a practice to introduce about 4 fluid ounces of kerosene. One grower reported that he used about a teaspoonful of phosphorus paste for this purpose. The benefit derived from these treatments was not determined, but they would seem unnecessary where the work of extraction is thoroughly done. All would tend to increase the cost of this method of control and some may be definitely injurious.

By simple extraction the writer has saved specimen palms on the station grounds that were being severely attacked. A number of coconut growers in the western section of the island have also used this method and with such success that they have made it a part of their standard plantation practice. The only disadvantages are that it requires regular and continuous inspection for several years and that it may not reduce so quickly the population of the beetle, and therefore the chance for attack, as some of the other more direct measures.

Collection of the adults and larvae found in decayed wood has destroyed breeding places as well as reduced the beetle population directly. Leonard (*7, p. 127*) reported a clean-up campaign having this objective conducted by the agricultural extension division of the Puerto Rico Department of Agriculture and Commerce in 1930–31. This was 2 years after extensive wind damage by the hurricane of 1928. In 17 municipalities in the western, northern, and eastern sections of the island, a total of 25,498 beetles and 370,844 larvae were collected from September to the following July. A bounty of 5 to 10 cents a dozen was paid for these insects, and the total cost amounted to $3,354.49.

Mellado, Jr. (*11, p. 29*) reported the preliminary results of a clean-up campaign begun by the Puerto Rico Emergency Relief Administration in February 1935, about 2½ years after the hurricane of 1932. As part of this campaign, a bounty of 1 cent was paid for each beetle and ½ cent for each larva delivered to the superintendent in charge. In 3 days 2,405 beetles were collected in 1 large grove alone, near Río Grande, where some 22,000 palms had been blown down. In the same length of time, 2,567 beetles were collected in several smaller groves at Loiza Aldea, where proportionate losses had been sustained. The former collection is shown in figure 11. From February to May 1935, a total of 63,110 beetles and larvae were collected in these and other groves in the northern and eastern sections of the island.

One advantage of this method of suppression is that it automatically reduces the number of breeding places available to this pest. In collecting the insects it is necessary to tear the decaying wood apart and in so doing this breeding material is rendered unsuitable for further use as an oviposition medium by the beetle. A serious disadvantage is that it leaves undestroyed wood as yet undecayed but which later may become infested by beetles that have already emerged.

Trapping

Light traps have offered little advantage in the control of this insect. While some beetles may be seen at lights at various times throughout the year, the total catch, even during the summer months of greatest abundance, has been insignificant. The number captured in two light traps operated in a grove during the 11 months from September to

FIGURE 11.—2,405 adults of *Strategus quadrifoveatus* collected in 3 days from decaying coconut logs and stumps during a clean-up campaign begun in February 1935 by the Puerto Rico Emergency Relief Administration. This collection was made in 1 grove on the northeast coast, where 22,000 palms had been blown down by the hurricanes of 1928 and 1932. Note typical thinned-out appearance of grove in background and poor stand of replants (*11, p. 29*).

July, mentioned under Habits of the Adult, p. 15, averaged only two beetles per month. Over two-thirds of these were females, some gravid and ready to start a new generation. Nevertheless, the total number caught by this means was only a small proportion of those observed to be emerging and already present in the vicinity of the lights.

Trash traps, composed of pieces of decayed coconut wood piled together at convenient places in the grove, appear to be much more promising, especially when used in connection with grove sanitation. If all other decayed wood in the grove is destroyed, the beetles remaining will be attracted to these traps as a place in which to lay their eggs. The piles can then be torn apart every several months and the beetles, eggs, and larvae found therein destroyed. This method was mentioned by Van Zwaluwenburg as being used by some growers in Puerto Rico, the wood being covered loosely with soil (*21, p. 44*). It was later recommended by Smyth (*17, p. 141*), who stated that it had been used successfully against the Solomon Islands rhinoceros beetle, *Oryctes*, in Samoa (*18, p. 124*).

An indication of the number of stages that can be trapped was obtained from a small bed of decayed coconut wood located in a grove in which there was also present a considerable amount of other infestive material. This bed, established in October, was 6 feet square by 10 inches deep. Each month, until August of the following year, the contents were examined for any stages of the beetle that might be present. The results of these examinations are shown in table 4.

TABLE 4.—*Rhinoceros beetle stages collected from November to August in trash trap in coconut grove containing other infestive material*

[Trap 6 feet square by 10 inches deep, established in October]

Month examined	Rhinoceros beetle stages found			Total
	Adults	Eggs	Larvae	
	Number	*Number*	*Number*	*Number*
November	0	0	1	1
December	1	0	0	1
January	0	2	0	2
February	0	12	3	15
March	0	0	3	3
April	0	0	16	16
May	2	7	15	24
June	0	11	52	63
July	1	3	20	24
August	1	13	7	21
Total	[1] 5	48	[2] 117	170

[1] 4 of these were females.
[2] Comprised of 89 larvae of the first instar, 26 of the second, and 2 of the third.

It will be seen in table 4 that during the 10 months this trap was in operation, a total of 170 insects was collected in various stages of development. The bulk of these were small larvae that came from eggs laid by attracted adults. Only 5 adults were actually found in the trap. No doubt more insects would have been captured had there been no other material available for oviposition in the grove.

Like the hand collection of larvae in scattered pieces of decayed wood, this method, when conscientiously followed, has the advantage of destroying the eggs and resulting larvae before they have an opportunity to develop into adults and attack young palms. An important disadvantage is that inspection of the trash piles is apt to become laborious or may be neglected altogether. If the piles of decayed wood are not thoroughly inspected and all stages of the beetle destroyed, they will be a menace rather than a benefit.

Insecticides

On account of their feeding habits, the adults and larvae of the coconut rhinoceros beetle are not very susceptible to control by means of insecticides. However, under certain circumstances it may be possible to poison some individuals in one or both stages.

Paris green was suggested by Smyth (*19, p. 29*) for making piles of discarded coconut husks in the grove permanently poisonous to the larvae. He recommended wetting the husks thoroughly with a sus-

pension of 2 pounds of paris green in 100 gallons of water. This suggestion was based on the belief that the larvae would feed on coconut husks, and its effectiveness was not determined.

Biological Control

Infection of trash (decayed wood) traps with the green muscardine fungus has been suggested (*17, p. 141*), but so far as the writer can find there is no record of its having been tried. Like insecticides, this entomogenous fungus offers possibilities of making such traps self-maintaining. However, since fungi are dependent on the presence of a certain degree of moisture for best propagation, additional attention from this standpoint would have to be given this kind of trap to keep it in working condition.

Protectors and Repellents

Probably more measures to protect newly planted palms mechanically from attack or to repel the beetle have been recommended or used than any other kind of control. Some, judging from their character, have undoubtedly been the result of desperate efforts on the part of the growers to control this persistent insect. In the present work, opportunity was afforded to observe the reaction of the beetle to a number of these measures.

A trial of a wire-cloth protective wrapping and a lime-sulfur-gas-tar repellent dip was made on a field basis. This trial extended for 43 months after planting, or over the most vulnerable period in the life of the palm. The results, as previously reported, showed 96-percent control by the wire-cloth wrap as compared with only 3 percent by the repellent dip (*14, pp. 113–115*). As this amount of control would suggest that much can be gained by the use of the wire-cloth wrap, a working description is given of its application.

Galvanized-iron-wire cloth of a standard grade having meshes ½-inch square was wrapped about the nut and lower 5 to 6 inches of the sprout of seedling palms immediately before planting. This size of mesh was large enough to accommodate easily the largest roots, which are about ⅜ inch in diameter (*3, p. 1*), and still small enough to prevent the entrance of the smallest beetle. Galvanization acted as a solder to hold the wires in place and thus prevent the beetles from enlarging the meshes. Ungalvanized material with electrically welded cross wires would probably have served the same purpose, but was not obtainable for this experiment.

A 2-foot length of the 24-inch-width material having two selvage edges was sufficient to enclose the average side-sprouted nut with few roots, usually employed in planting (*5, p. 8*). The cloth was bent along the diagonal and, with the nut placed in the center, two opposite corners were brought together around the base of the sprout, as illustrated in figure 12,*A* and *B*. It is important that the corners of the wire cloth be carefully fitted so that the beetle cannot enter by pulling the wires apart; yet the wires should not restrict the normal growth expansion of the sprout. With a little practice, one man could thus prepare about six palms per hour.

In planting, the seedling is set with the top of the nut level or nearly level with the surface of the soil, as shown in figure 12,*C*, so that the base of the sprout is protected for from 5 to 6 inches above ground.

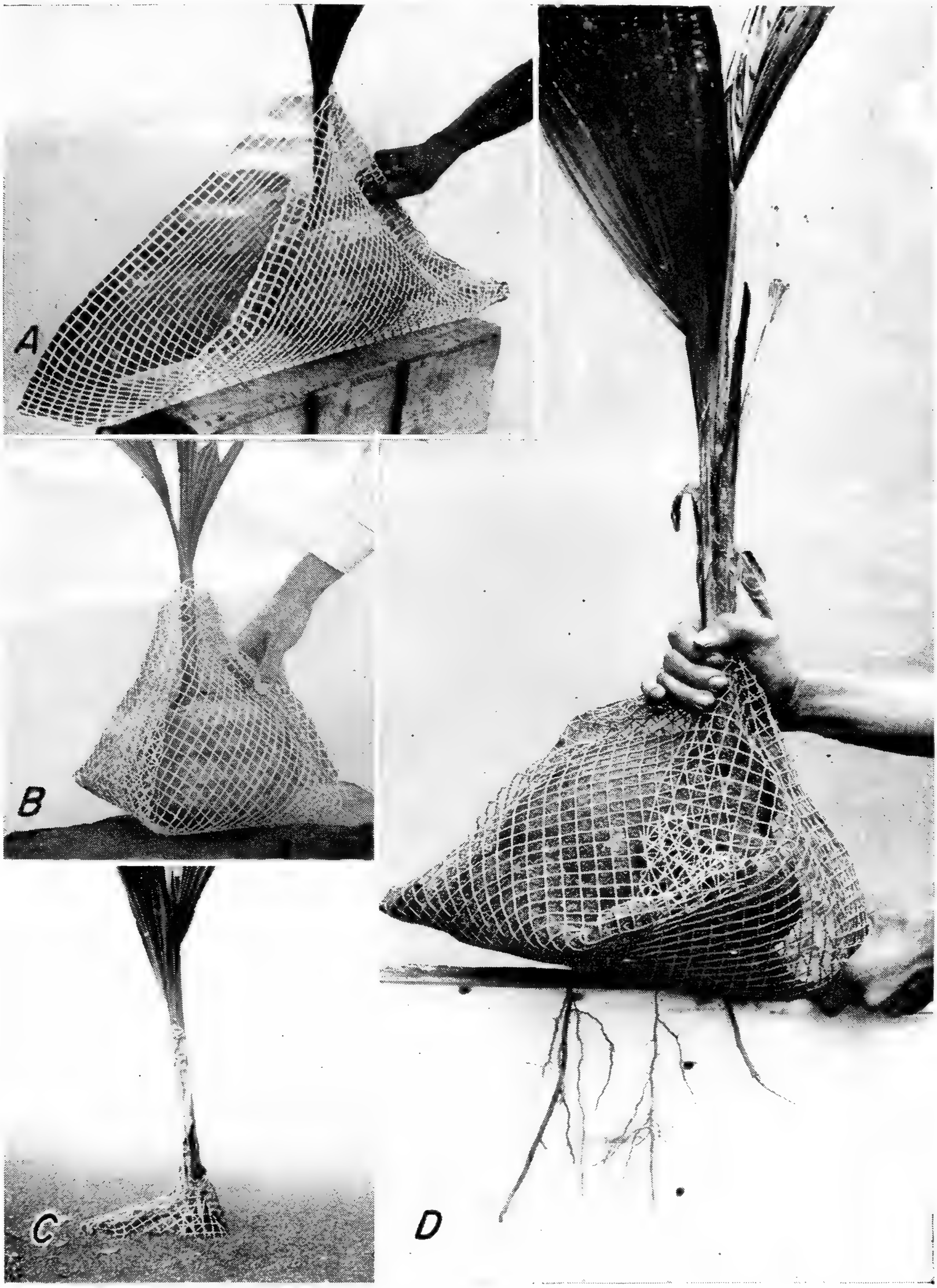

FIGURE 12.—Wrapping seedling coconut palms in ½-inch square-mesh galvanized-iron wire cloth as protection against attack by adults of *Strategus quadrifoveatus: A*, Adjacent edges of a diagonally bent 2-foot-square piece of wire cloth are folded into flat seams about each side of sprout; *B*, wrap is completed by folding points of flat seams up over ends of nut and closing all 4 corners of wire cloth by pressing or loosely fastening about lower 5 to 6 inches of sprout. In planting, top of nut (under operator's thumb) is set flush with soil surface; *C*, palm planted to show wire extending above ground about base of sprout; *D*, same palm 9 months later, showing freedom from attack, normal top growth, and unhampered root development. This protection worked perfectly for several years, so long as wires were not accidentally opened or soil thrown up over them by cultivation.

Practically no subsequent care is needed to maintain this protection in perfect working condition for several years. However, when livestock gains access to the grove the animals are apt to open the wires by trampling. Cultivation too close to the palm may also accidentally open the wires or mound up soil high enough for the beetles to gain foothold above the top margins of the wire about the base of the sprout. Under these conditions, it is necessary to repair all damage as soon as possible and at the same time remove all soil from the top of the wire.

The palms in the field trial referred to above were wrapped, planted, and cared for in the manner just described. In all cases growth seemed to be normal in every way (*14, pp. 114–115*). Unhampered root development, typical of that found during early growth of the wire-wrapped palms, is shown in figure 12,*D*. Growth to maturity was comparable to that made by the untreated palms that survived beetle attack.

Slight increase in the cost of planting stock and exercise of the foregoing precautions are the only important disadvantages of this method of control. However, these are more than counterbalanced by the saving of practically all the palms from rhinoceros beetle attack and reducing the need for replanting.

Two other methods of mechanical protection have been used to a small extent in the western section of the island. One was observed to be ineffective, the other injurious.

Wild pineapple, locally known as "maya," was planted by some growers around palms that had recently been set out. The species used was *Bromelia pinguin* L., which has stout curved spines on the edges of the leaves and on this account is commonly employed for making impenetrable living fences. In using this method of protection, the belief was that the spines would impale the beetle or otherwise prevent it from gaining access, particularly by flight, to the base of the palm. Actually, however, this treatment did little more than seriously interfere with adequate inspection of this region and the destruction of any beetles present. The beetles seemed to have no difficulty in entering, for no less evidence of their attack was found in the treated palms than in the untreated ones.

A concrete collar was used in one grove to keep the beetles from entering the soil close to the palm. About a 1-inch layer of concrete such as that ordinarily used for building purposes was spread in the shape of a low dome around the base of the young palm. The surface of the soil was thus sealed about the sprout for a radius of about 12 inches. This protection appeared to be effective in about 12 palms that were examined at random. However, the majority of these were undoubtedly suffering a great deal from constriction of the trunk. Even those palms which broke the concrete had a somewhat chlorotic appearance and seemed to be less vigorous than those that were not treated.

Hydrated lime has been employed to some extent as a protective application about the base of newly planted palms (*22, p. 34; 23, p. 375*). In a replicated cage test of this treatment, about 2 pounds of hydrated lime was used for each palm. This was spread evenly in the form of a disk that averaged ½ inch in thickness and 6 inches in radius. About 1 inch of rainfall during the first day after treatment caused the lime to become hard. However, it was not sufficiently

hard to prevent the beetles from making holes through most of the disks, or from burrowing underneath and breaking up the others within 3 months. Of the 12 palms treated, 8 were attacked during this time and 3 of these were killed in from 6 to 61 days. Undoubtedly more palms would have become fatally attacked had the test been continued for a longer period. One of the untreated palms used as checks was killed in 11 days and the other in 63 days after treatment. The field application of hydrated lime as here used would seem to offer little promise of more than temporary protection against this insect.

Salt has been suggested from time to time as having protective properties (*19, p. 28; 22, p. 34; 23, p. 375*). For qualitative observation, 1 pound of locally made sea salt about the size known as "half-ground" was applied per palm in the manner described for lime. The disk of salt was not quite so thick, however, and had a radius of only about 5 inches. During the first 2 days after treatment 0.27 inch of rain melted nearly half of the amount applied but still left an appreciable covering over the ground about the sprout of the palm. The beetles did not burrow directly through the salt from above, but evidence of their burrowing underneath was seen in about 2 months after treatment, and death of the young palms followed shortly afterward. Under more severe conditions in the field it is quite likely that more salt than here used would be required to produce even this small amount of protection.

The possible protection that might be afforded by a strong repellent, such as "tar oil," "carbolinium," or "crude petroleum," applied to the husk before planting was suggested by Smyth (*18, p. 124; 19, pp. 28–29*). The following materials were chosen for observation as being in the same class as these but less apt to be injurious to the seedling palm: (1) Trinidad asphalt, heated to 158° C., was used as a dip for both unsprouted and sprouted nuts. The sprouted nuts were covered to about 3 inches above the base of the sprout, and these and the unsprouted nuts retained a tough coating that averaged 535 grams in weight and from 1/16 to 1/8 inch in thickness. (2) Gas tar from a local gas company was similarly used, but the coating, averaging 213 grams per nut, was only about as thick as a piece of hardware paper. (3) Roofing paper, a single-ply, medium-weight grade, was folded as closely as possible about the nut and lower 3 inches of the sprout and held in place with 1-inch roofing nails; over this was applied a heavy brushing coat of a creosote solution having the odor of wood smoke. It was purchased locally under the name "carbolina."

None of these treatments appeared adversely to affect sprouting or normal growth. The creosoted-paper wrap seemed to give the best results but was good only for about 3 months. This is little longer than many untreated palms remain unattacked in the field. Considering their added cost of application and poor protective powers under these conditions, it is probable that none of these treatments would be commercially practicable.

Double-strength self-boiled lime-sulfur was likewise observed for repellent properties. To increase the sticking qualities of this mixture, aluminum sulfate was added at the rate of 3 pounds for each 20 pounds of lime. The nut and lower part of the sprout was thoroughly coated by dipping and allowed to dry before planting. In preventing

entrance of the beetles, this was no more effective than any of the foregoing dip treatments.

Grove Sanitation

Destruction of infestive material in or near the grove was probably the earliest recommendation made to control the coconut rhinoceros beetle. This was suggested in 1915 by Van Zwaluwenburg (*21, p. 44*) and later reiterated by Smyth (*19, p. 29*) and Wolcott (*23, p. 377*). It seems reasonable that sanitation would be as effective against this insect as it has been against other insects elsewhere. However, the natural desire to keep maintenance costs low, once the grove is planted, and the great amount of labor needed for sanitation, especially following heavy wind damage, have helped to make this method impracticable for some growers. To be fully effective it has to be carried out on a community-wide basis and cover extended areas in the vicinity of new plantings. Every possible breeding place must be located and destroyed so that no distant as well as local supply of decaying wood, particularly logs and stumps of coconut and other trees, will serve as a source of infestation.

The extensive clean-up campaign of the Puerto Rico Emergency Relief Administration already mentioned aimed to reduce by this method the great loss of palms replanted after the hurricanes of 1928 and 1932. Started on February 1, 1935, this campaign originally covered the north coast of the island from San Juan east. On August 1 of that year it was extended under funds made available successively by the Puerto Rico Emergency Relief Administration, Federal Emergency Relief Administration, and Puerto Rico Reconstruction Administration, to include the remainder of the island. Laborers were employed under supervision to cut up and burn all dead and decayed wood in such locations. In addition, the collection of beetles and larvae on bounty was continued as described under Hand Collection, p. 22. Efforts were made to destroy all diseased and dead palms both standing and felled, as well as all palm fence posts and all palm stumps. To facilitate burning, large pieces were first split and piled loosely until dry.

In practice, it was not always possible to locate all of this infestive material in the neighborhood of some groves. This was particularly true where the ground previously occupied by wind-felled palms was planted to a crop, such as sugarcane, that covered up the decaying logs and stumps. However, in sections where there was a minimum of this kind of interference, as on the northeast coast of the island, it is understood that a material decrease in the loss of newly planted palms followed during the next year or two after the work had been completed.

Some idea of the benefit derived under more difficult conditions was obtained from experimental plantings on the west coast. These plantings were made in two groves located on Añasco bay about 8 miles north of Mayaguez. Both groves contained about 3,000 bearing palms and had experienced about the same loss of replants. Sugarcane covered much of the adjoining land previously occupied by wind-felled palms and also not far away were small pieces of thinly wooded land, all of which interfered greatly with thorough inspection and sanitation.

Seven months after cleaning operations had been completed in most of that region, 40 seedling coconut palms were planted in one grove near the center of the area. At the same time, 40 similar palms were planted as controls in the other grove where sanitary measures were delayed for more than a year. The area cleaned extended to within one-eighth mile of the location of the control palms. The method and distance of planting followed customary practices of that section, and the palms were examined monthly for general condition and evidence of beetle attack. The condition of the palms by the end of various periods after planting in both locations is summarized in table 5.

TABLE 5.—*Seedling coconut palms killed by the coconut rhinoceros beetle by the end of various periods after planting in a grove area cleaned of decaying wood and in another area not so cleaned*

[40 palms planted in each area May 1936]

Period after planting (months)	Palms attacked in cleaned area [1]			Palms attacked in uncleaned area [2]		
	Total	Killed		Total	Killed	
	Number	*Number*	*Percent* [3]	*Number*	*Number*	*Percent* [3]
1	1	0	0	8	3	7. 5
4	4	0	0	18	14	35. 0
7	6	1	2. 5	21	16	40. 0
10	7	3	7. 5	24	19	47. 5
13	9	3	7. 5	30	21	52. 5
37	15	11	27. 5	37	33	82. 5

[1] Cleaned October 1935.
[2] Cleaned June 1937.
[3] Based on number of palms planted.

It will be noted in table 5 that during the first 7 months after planting in the cleaned area six palms became attacked by the beetle and one was killed. During the same period where grove sanitation had not been practiced, over half the palms were attacked and 40 percent were killed. By the end of 13 months, 7.5 percent of the former were dead from this cause, as compared with 52.5 percent of the latter. A final examination was made about 2 years after an extension of the clean-up campaign had been concluded in the control grove. By this time, 37 months after planting, the number of palms killed by the beetle in the first area had increased to 27.5 percent of those originally planted, while that in the control area had increased to 82.5 percent.

During these intervening 2 years, the increase in percentage of experimental palms killed in both areas was considerable. Apparently some new source of infestation developed or was overlooked in the cleaning operations. However, this increase was much less in the original cleaned-up area than in the other. Under these conditions, the final total reduction of 67 percent in loss from the beetle indicates a substantial saving of replants through the practice of grove sanitation.

Other Cultural Methods

Fall planting has been indicated as likely to favor survival. Planting at this time of the year avoids the peak of adult emergence previ-

ously noted to occur in June and July. It also takes advantage of a period of heavy rainfall in which to establish the new palms.

The benefit of following such a practice was shown by the incidence of infestation found among the 80 palms reported in table 5. These palms were planted in May on the west coast of the island where the rainfall was estimated to approximate that shown in table 2. Periodical examination revealed that 22 palms became attacked by the beetle (14 fatally) during the 4 months from May to the latter part of September. Only 9 palms were attacked (8 fatally) during the next 6 months of October to March, and 8 (2 fatally) during the following 3 months or between March and June. Although not shown in table 5, the monthly increase in infestation during the 6 months of August to January was about the same as that from October to March. The former period coincides with the period of greatest rainfall in most of the principal coconut districts of the island, and the first 2 months of this period are usually the wettest (*20, pp. 5–10*). In general, therefore, August and September would seem to be the best months in which to plant, not only to minimize rhinoceros beetle attack but also to secure best early growth of the young palms.

Varietal resistance offers some promise of reducing liability to attack but needs trial on a large scale. A small planting of 3 Malay varieties of dwarf coconuts was made in June 1936 at Tres Hermanos; some native seedlings planted nearby at about the same time served as controls. These varieties had been introduced in 1933 and 1934 by the Federal Experiment Station through the Bureau of Plant Industry, Soils, and Agricultural Engineering, and were sprouted on the station grounds at Mayaguez. Only 18 palms of what was designated as the "green" variety, 11 of the "red," and 22 of the "yellow" were available for comparison. Although these numbers were too small for the results to be conclusive, the green variety was attacked the least (*13, p. 94*), and also seemed to be much less susceptible than the native seedlings. During the 7 months of observation after planting, 11 percent of the green variety, 18 percent of the red, and 14 percent of the yellow were killed by the bettle; among 40 native controls nearby fatal attack amounted to 38 percent.

SUMMARY AND RECOMMENDATIONS

The coconut rhinoceros beetle (*Strategus quadrifoveatus* (Palisot)) has been recognized as a serious pest of young coconut and other palms in Puerto Rico for many years. The hurricanes of 1928 and 1932 blew down more than half of the bearing palms in many sections of the island. Several years later, the beetles developing from eggs deposited in the decaying trunks killed about 50 percent of the palms that were replanted.

Hatching in about 17 days, the larvae, among the largest white grubs known, pass through three instars and become full grown in about 14 months. Normally feeding on decaying coconut wood, they can develop to maturity in the wood of a number of other plants. Fence posts made of coconut palm wood quickly become infested. Coconut husks serve only as an accidental breeding medium.

A prepupal stage of 18 days and a pupal stage of 33 days are spent in a cell formed by the full-grown larva in the decayed wood in which it develops.

The dark reddish-brown adult with highly polished thorax and wing covers varies in size up to 60 mm. long for the males and to 50 mm. long for the females. The front of the prothorax of the male bears three horn-like projections, the middle and much longer of which has a slightly upward turn and comes to a single point; whence the common name rhinoceros beetle.

Two distinct movements of the adults were evident from the preferences shown by different-aged beetles for different parts of the coconut palm: The first movement, soon after emergence, from decayed wood to young coconut palms for food and mating; and the other, of older beetles, back to decayed wood for oviposition.

When extremely numerous the adults may attack other palms both young and old and the tops of bearing coconut palms, and may also hollow out the inside of sugarcane stalks. Although nocturnal, they are only slightly attracted to lights.

Observations on development indicated an average period from egg to emergence of the adult of 496 days and complete life cycle from egg to egg of 595 days.

All stages except the egg were found in the field or obtained in the laboratory in every month of the year. Eggs were found in greatest abundance in June and July. Larvae of early instars predominated during the summer months, those of the last instar during the winter. Pupae reached their peak in May. Adults were most abundant in June and July.

No internal parasites were encountered on any stage of this insect. The green muscardine fungus was found on a few field-collected larvae. Mites of two families, one truly parasitic, occurred on the larvae and sometimes on the adults, but these, too, failed to exert any apparent control. Larvae of *Pyrophorus luminosus* and adults of *Plaesius javanus*, both predators of the larvae of other insects, but not found associated with this pest in the field, fed avidly on larvae of the coconut rhinoceros beetle under laboratory conditions.

A number of methods of control that have been recommended from time to time are discussed and the results given of tests of the most promising.

Destruction of the adults while they are attacking young palms has given immediate results and is highly recommended for use in seedbeds and nurseries and on a plantation scale.

Collection of the adults and larvae found in decayed wood has destroyed breeding places as well as reduced the beetle population directly.

A wire-cloth covering of the nut and lower part of the sprout protected newly planted palms from attack so long as the wire extending above ground was not accidentally opened or soil thrown up over it by cultivation. This method is recommended where it is impracticable to destroy all breeding places or only a few palms are set out, as in replanting small areas.

Creosote-coated roofing paper similarly applied and dips of asphalt, gas tar, lime-sulfur with gas tar, and double-strength self-boiled lime-sulfur afforded little or no protection. Both hydrated lime and salt placed around the base of newly planted palms failed to keep the beetles from burrowing into the soil and attacking the sprout.

Grove sanitation reduced by 67 percent the loss of palms replanted in an area in the western section of the island following the hurricane of 1932. This and nearly equal effectiveness estimated in other sections recommend this method as most desirable under all conditions, but especially when large areas are planted for the first time or replanted following extensive wind damage.

August and September were indicated as the best months for planting to minimize rhinoceros beetle attacks and to take advantage of the most favorable growing conditions for the young palms.

Three Malay varieties of dwarf coconuts were attacked less than native seedlings, but the numbers available for comparison were too small for the results to be conclusive.

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U. S. GOVERNMENT PRINTING OFFICE: 1948